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A Check-List of the Fishes of the Riu-Kiu Islands

By PROF. P. SCHMIDT
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The list is compiled after the contributions of Brevoort, Snyder, Jordan and Starks, Tanaka and other previous authors, as also after my own study of a collection of fishes made on the Amami-Oshima and on the Okinawa Islands in December, 1926, and January, 1927, and containing 164 species of marine fishes†. A small list of 11 species of fishes from the Okinawa Island was added after a collection made by Dr. K. Awaya (Naha) and studied by me in 1929.

The 457 species known from the Riu-Kiu Islands now represent surely not more than a half of the exceedingly rich tropical ichthyofauna of these islands. Further studies are needed, inasmuch as this region is highly interesting being the northern limit for the true tropical fishes and for the coral reefs fauna.

A.—Amami-Oshima Island.
O.—Okinawa Island.
Y.—Yaeyama (Miyako) Island.
*—Added by my collection to the ichthyofauna of the Riu-Kiu Islands.

SELACHII

Fam. Galeidae.

1. Calliscyllium venustum Tan. O.

Fam. Scylliorhinidae.

2. Stegostoma tigrinum Gmel. O.

Fam. Aetobatidae.

3. Aetobatus tobijei Blk. O.

Teleostei.

Fam. Albulidae.

4. Albula vulpes L. Y,O *

Fam. Elopidae.

5. Elops machnata Forsk. O.
6. Megalops cyprinoides Brouss. O.

Fam. Clupeidae.

7. Harengula okinawensis Kish. O.

Fam. Salmonidae.

8. Plecoglossus altivelis Schl. A.

Fam. Synodontidae.

9. Synodus japonicus Houtt. O,A.
10. Saurida argyrophanes Rich. O.
11. Saurida nebulosa Sol. O.
12. Saurida gracilis Q.G. O.
13. Trachinocephalus myops Forst. A *

Fam. Plotosidae.

14. Plotosus anguillaris Bl. O.

Fam. Chanidae.

15. Chanos chanos Forsk. O.

Fam. Congridae.

16. Conger cinereus Rüpp. O.

Fam. Myridae.

17. Muraenichthys owstoni Jord. & Sn. Y,O.

Fam. Ophichthyidae.

18. Ophichthus (=Microdonophis) polyophthalmus Blk. O.
19. Microdonophis erabo Jord. & Sn. O.
20. Pisoodonophis cancrivorus Rich. O.
21. Myrichthys rupestris Sn. O.
22. Myrichthys (=Chlevastes) colubrinus Bodd. Y.
23. Callechelys melanotaenia Blk. Y.
24. Leinranus semicinctus Lay & Ben. Y.
25. Aphthalmichthys (=Moringua) abbreviatus Blk. Y.

Fam. Muraenidae.

26. Gymnothorax meleagris Shaw & Nodd. (=G. laysanus Steind.). O.
27. Gymnothorax pictus Ahl. O.
28. Gymnothorax undulatus Lac. (=G. stellatus Lac.). O.
29. Gymnothorax petelli Blk. O.
30. Gymnothorax albomarginatus Schl. O.
31. Gymnothorax philippinus Jord. & Seale. O.
32. Gymnothorax chlamydatus Sn. O.
33. Strophidon brummeri Blk. Y.
34. Echidna nebulosa Ahl. O.
35. Echidna delicatula Blk. O.
36. Echidna polyzona Rich. O.
37. Uropterygius okinawae Jord. & Sn. O.

Fam. Monopteridae.

38. Monopterus albus Zuiev. O.

Fam. Hemirhamphidae.

39. Hyporhamphus dussumieri C. V. O.
40. Hemirhamphus commersoni Cuv. O.
41. Hemirhamphus japonicus Brev. O.

Fam. Belonidae.

42. Tylosurus schismatorhynchus Blk. O *
43. Tylosurus giganteus Schl. O.

Fam. Exocoetidae.

44. Parexocoetus brachypterus Sol. O.

Fam. Fistulariidae.

45. Fistularia petimba Lac. O.
46. Fistularia serrata Cuv. O.

Fam. Syngnathidae.

47. Corythroichthys ischigakius Jord. & Sn. O.
48. Microphis extensus Sn. O.
49. Microphis ocellatus Sn. O.
50. Ichthyocampus nox Sn. O.
51. Hippocampus aterrimus Jord. & Sn. O.

Fam. Centriscidae.

52. Centriscus strigatus Gthr. Y.

Fam. Sphyraenidae.

53. Sphyraena obtusata C. V. O.
54. Sphyraena commersoni C. V. O.

Fam. Atherinidae.

55. Hepsetia insularum Jord. & Everm. Y.

† A paper containing a more detailed study of this collection will be published in "Transactions of the Pacific Committee of the Academy of Science of the USSR," Vol. I.

56. Atherina woodwardi Jord. & St. O.
57. Atherina tsurugae Jord. & St. O *

Fam. Mugilidae.

58. Mugil cephalus L. O.
59. Mugil affinis Gthr. O *
60. Liza troscheli Blk. O.

Fam. Holocentridae.

61. Holocentrus ittodai Jord. & Fowl. O.
62. Holocentrus furcatus Gthr. (=H. ensifer Jord. & Everm.). Y *
63. Holocentrus microstomus Gthr. A *
64. Holocentrus sammara Forsk. O.
65. Holocentrus binotatus Q. G. O.
66. Holocentrus ruber Forsk. (=H. praslin Lac.). O.
67. Holocentrus lacteoguttatus C. V. (=H. punctatissimus C. V.). O.
68. Myripristis murdjan Forsk. O.
69. Myripristis macrolepis Blk. O.

Fam. Scombridae.

70. Euthynnus (=Gymnosarda) alleteratus Raf. O.
71. Acanthocybium sara Lay & Ben. O.

Fam. Carangidae.

72. Scomberoides sancti-petri C. V. O.
73. Scomberoides orientalis Schl. A.
74. Trachurops crumenophthalmus Bl. Y,O.
75. Trachurus argenteus Wak. O.
76. Seriola purpurascens Schl. O *
77. Seriola quinqueradiata Schl. O.
78. Seriola cristata Doed. O.
79. Seriola intermedia Schl. O.
80. Selar macrophthalmus Rüpp. O *
81. Selar mauritianus Q. G. O.
82. Decapterus macrosoma Blk. O.
83. Decapterus russelli Rüpp. O.
84. Caranx jarra C. V. O.
85. Caranx ignobilis Forsk. Y,O.
86. Caranx ferdau Forsk. O.
87. Caranx ciliaris Bl. A *
88. Caranx plumbeus Q. G. O.
89. Caranx uii Wak. O.
90. Caranx oblongus C. V. O.
91. Caranx deani Jord. & Saale. O.
92. Caranx tanakai Wak. O.
93. Caranx dinema Blk. O.
94. Caranx hemigymnosthetus Blk. O,A *
95. Caranx forsteri C. V. O.A.
96. Caranx sex-fasciatus Q. G. A *
97. Caranx xanthopygus C. V. O.
98. Caranx bixanthopterus Rüpp. O.
99. Caranx ascensionis Osb. (=C. melampygus C. V.). Y *
100. Caranx sansun Forsk. O,A *
101. Caranx djeddaba Forsk. O *
102. Caranx mate Cuv. (=C. affinis Rüpp.). O.
103. Caranx platessa C. V. A *
104. Caranx mertensi C. V. O.
105. Caranx micropterus Rüpp. O.
106. Caranx uraspis Gthr. O.
107. Caranx leptolepis C. V. O.
108. Caranx breviventris Wak. O.
109. Trachinotus bailloni Lac. O.
110. Trachinotus cuvieri Wak. O.
111. Trachinotus quadripunctatus Rüpp. O.
112. Leiognathus edentulus Bl. Y.
113. Naucrates indicus C. V. Y,O.
114. Elagatis bipinnulatus Q. G. O.

Fam. Trichiuridae.

115. Trichiurus haumela Forsk. O.

Fam. Pempheridae.

116. Pempheris mangula Cuv. (=L. vanicolensis C. V.). O.
117. Pempheris otaitensis Less. (=P. oualensis C. V.). O.

Fam. Cheilodipteridae.

118. Apogonichthys variegatus Val. O *
119. Apogonichthys nafae Sn. O.
120. Apogon novemfasciatus C. V. O.
121. Apogon bandanensis Blk. (=A. savayensis Gthr.). O.
122. Apogon lateralis Val. O.
123. Apogon erythrina Sn. O.
124. Apogon amboinensis. A.

Fam. Kuhliidae.

125. Safole taeniura C. V. O.
126. Kuhlia marginata C. V. A *
127. Kuhlia rupestris Lac. O.

Fam. Serranidae.

128. Diploprion bifasciatus K.u., V. H. O *
129. Plectropoma naculatum Bl. O *
130. Variola louti Forsk. O.
131. Variola flavimarginata Rüpp. O.
132. Cephalopholis sonnerati C. V. O.
133. Epinephelus merra Bl. O.
134. Epinephelus fasciatus Forsk. O.
135. Epinephelus megachir Rich. O.
136. Epinephelus stellans Rich. O.
137. Epinephelus tsirimenara Schl. O.
138. Epinephelus awoara Schl. O.
139. Epinephelus tauvina Forsk. O.
140. Epinephelus dispar Hayf. O *
141. Epinephelus coeruleopunctatus Bl. O.
142. Epinephelus summana Forsk. O.
143. Epinephelus rhyncholepis Blk. O.
144. Epinephelus hemistictus Rüpp. A *
145. Epinephelus urodelus C. V. O,A *
146. Epinephelus aurantius C. V. A *
147. Plesiops melas Blk. O.
148. Pseudanthias taira Schmidt. A *
149. Franzia rubra Tan. A *
150. Centrogenys waigiensis Q. G. O.

Fam. Lutianidae.

151. Lutianus rivulatus C. V. O.
152. Lutianus quinquelineatus Bl. O.
153. Lutianus argentimaculatus Forsk. O,A.
154. Lutianus vitta Q. G. O.
155. Lutianus russeli Blk. A *
156. Lutianus marginatus C. V. O.
157. Lutianus fulviflamma Forsk. Y *
158. Lutianus monostigma C. V. O.
159. Lutianus unimaculatus Bl. O.
160. Genyoroge kasmira Forsk. Y,O.
161. Genyoroge bottonensis C. V. O *
162. Genyoroge gibba Forsk. A *
163. Aprion virescens C. V. O.
164. Platyinius amoenus Sn. O.
165. Aphareus furcatus Lac. O,A *

Fam. Haemulidae.

166. Caesio erythrogaster C. V. O.
167. Caesio coerulaureus Lac. O.
168. Caesio chrysozonus K.u.V.H. O.

Fam. Theraponidae.

169. Therapon servus Bl. Y *
170. Therapon yarbua Forsk. O.
171. Plectorhynchus crassispinus Rüpp. A *
172. Plectorhynchus diagramma Lac. O.
173. Plectorhynchus chaetodonoides Lac. O.
174. Pomadasis argenteus Lac. O.

175. Pomadasis hasta Bl. O.
176. Scolopsis cancellatus C. V. O.
177. Scolopsis bilineatus Bl. O,A.
178. Pentapus microdon Blk. O.
179. Pentapus formosulus Sn. O,A.
180. Pentapus aurolineatus Lac. Y,O.
181. Nemipterus taeniopterus C. V. O *
182. Nemipterus furcosus C. V. O *

Fam. Sparidae.

183. Lethrinus harak Forsk. O.
184. Lethrinus richardsoni Gthr. O.
185. Lethrinus amboinensis Blk. O.
186. Lethrinus reticulatus C. V. (=L. moensi Blk.). O.
187. Lethrinus glyphodon Gthr. Y*
188. Lethrinus miniatus Bl. Schn. O *
189. Lethrinus choerorhynchus Bl. Y,A *
190. Evynnis cardinalis Lac. O.
191. Sparus latus Houtt. O.

Fam. Kyphosidae.

192. Girella mezina Jord. & St. O.
193. Kyphosus lembus C. V. Y *

Fam. Gerridae.

194. Xystaema erythrourum Bl. O *
195. Gerres punctatus C. V. O,A *
196. Gerres argyreus Forst. O *
197. Gerres macrosoma Blk. Y *
198. Gerres subfasciatus C. V. Y *
199. Gerres abbreviatus Blk. Y *
200. Gerreomorpha japonica Blk. O.

Fam. Oplegnathidae.

201. Oplegnathus fasciatus Schl. O.

Fam. Mullidae.

202. Mulloides auriflamma Forsk. Y *
203. Mulloides japonicus Houtt. O *
204. Mulloides flavolineatus Lac. O.
205. Mulloides vanicolensis Ner. & Mont. O *
206. Upeneus spilurus Blk. Y *
207. Upeneus multifasciatus Q. G. (=U. moana Jord. & Seale). O.
208. Upeneus barberinus Lac. O.
209. Upeneus barberinoides Blk. O,A.
210. Upeneus dispilurus Playf. (=U. ischyrus Sn.). O.
211. Upeneus chryserydros Lac. (=U. cyclostomus Lac.). O,A.
212. Upeneus pleurospilos Blk. O.
213. Upeneus indicus Shaw. O.
214. Upeneus pleurostigma Ben. O.
215. Upeneoides bensasi Schl. O.
216. Upeneoides tragula Rich. O.
217. Upeneoides vittatus Forsk. O.

Fam. Cirrhitidae.

218. Goniistius zebra Doed. O.
219. Goniistius zonatus C. V. O.
220. Paracirrhites forsteri Bl. O.
221. Cirrhitichthys aprinus C. V. A *
222. Cirrhitus marmoratus Lac. A *

Fam. Polynemidae.

223. Polydactylus plebeius Brouss. O*

Fam. Pseudochromidae.

224. Dampieria spiloptera Blk. O.
225. Dampieria hellmuthi Blk. A *

Fam. Malacanthidae.

226. Malacanthus hoedtii Blk. (=M. parvipinnis V. & S.). O.
227. Malacanhus latovittatus Lac. O.

Fam. Pomacentridae.

228. Amphiprion polylepis Blk. O. Ben.). A *
230. Pomacentrus nigricans Lac. O.
229. Amphiprion polymnus L. (subsp. clarkii
231. Pomacentrus melanopterus Blk. O.
232. Pomacentrus tripunctatus Cuv. O.
233. Pomacentrus caudovittatus Schmidt. A *
234. Pomacentrus violascens Blk. O *
235. Chromis notatus Schl. O,A *
236. Chromis coeruleus C. V. O *
237. Dascyllus isharae Schmidt. A *
238. Abudefduf sordidus Forsk. O.
239. Abudefduf richardsoni Sn. O.
240. Abudefduf rex Sn. O.
241. Abudefduf zonatus C. V. O.
242. Abudefduf glaucus C. V. O.
243. Abudefduf cyaneus Q. G. O.
244. Abudefduf sexfasciatus Lac. O.
245. Abudefduf melas Cuv. O.
246. Abudefduf leucogaster Blk. O *

Fam. Labridae.

247. Choeredon anchorago Bl. Y.
248. Choerodon jordani Lac. O,A.
249. Lepidaplois hirsutus Lac. Y,O.
250. Lepidaplois mirabilis Sn. O.
251. Lepidaplois perditio Q. G. O.
252. Epibulus insidiator Pall. O.
253. Hemigymnus fasciatus Bl. O.
254. Hemigymnus melapterus Bl. O.
255. Anampses caeruleopunctatus Rüpp. O.
256. Anampses meleagrides C. V. O *
257. Anampses twistii Blk. O *
258. Anampses geographicus C. V. O.
259. Duymaeria flagellifera C. V. A *
260. Pseudolabrus japonicus Houtt. A *
261. Labrichthys cyanotaenia Blk. A.
262. Labropsis manabei Schmidt. O *
263. Crenilabrus steinegeri Ish. O.
264. Cirrhilabrus solorensis Blk. (=C. lyukyensis Ishik.). O.
265. Cheilinus oxyrhynchus Blk. O,A.
266. Cheilinus fasciatus Bl. O.
267. Cheilinus diagrammus Lac. O.
268. Cheilinus trilobatus Lac. O.
269. Cheilinus unifasciatus Str. A *
270. Cheilinus bimaculatus C. V. A *
271. Stethojulis casturi Gthr. O,A.
272. Stethojulis phekadopleura Blk. O.
273. Stethojulis axillaris Q. G. O.
274. Stethojulis strigiventer Ben. Y,O.
275. Stethojulis trossula Jord. & Sn. O *
276. Stethojulis maculatus Schmidt. A *
277. Stethojulis renardi Blk. O.
278. Halichoeres notopsis K. & V. H. O.
279. Halichoeres margaritaceus C. V. O.
280. Halichoeres meleagris C. V. O *
281. Halichoeres trimaculatus Q. G. O.
282. Halichoeres prosopeion Blk. O *
283. Hologymnosus semidiscus Lac. O.
284. Coris angulata Lac. O.
285. Coris variegata Rüpp. O.
286. Coris venusta Vail. & Sauv. O *
287. Coris gaimard Q. G. O.
288. Julis yamashiroi Schmidt. O *
289. Julis awayae Schmidt. O *
290. Julis albolumbata Schmidt. O *
291. Leptojulis pardalis Kn. O *
292. Thalassoma jansenii Blk. O.
293. Thalassoma umbrostigma Rüpp. O.
294. Thalassoma quinquevittatus L. & B. O.
295. Thalassoma amblycephalus Blk. O.
296. Thalassoma lutescens Sol. O.

297. Thalassoma hardwicke Ben. O.
298. Thalassoma trilobata Lac. A *
299. Thalassoma lunare L. O,A *
300. Cheilio inermis Forsk. O.
301. Cheilinus chlorurus Bl. O.
302. Novaculichthys taeniourus Lac. O.
303. Novaculichthys macrolepidotus Bl. O.
304. Iniistius dea Schl. O,A.
305. Gomphosus varius Lac. O.
306. Gomphosus tricolor Q. G. O.

Fam. Scarichthyidae.

307. Scarichthys auritus K. et V. H. A *
308. Leptoscarus viridescens Rüpp. Y,O *
309. Callyodon nuchipunctatus C. V. O.
310. Callyodon mutabilis Gray. O *
311. Callyodon pyrrostethus Rich. O.
312. Callyodon fasciatus C. V. O.
313. Callyodon lunula Sn. O.
314. Callyodon sordidus Forsk. O.
315. Callyodon oedema Sn. O.
316. Callyodon balinensis Blk. O.
317. Callyodon bicolor Rüpp. O.
318. Callyodon forsteri Blk. O.
319. Callyodon oktodon Blk. Y *
320. Callyodon chrysopomus Blk. Y *
321. Calotomus japonicus C. V. O.

Fam. Monodactylidae.

322. Monodactylus argenteus L. Y *

Fam. Platacidae.

323. Platax teira Forsk. O.

Fam. Chaetodontidae.

324. Chaetodon vagabundus L. O.
325. Chaetodon falcula Bl. (=Ch. ulietensis C. V.). O.
326. Chaetodon daedalma Jord. & Fowl. O.
327. Chaetodon lunula Lac. O.
328. Chaetodon citrinellus Brouss. O.
329. Chaetodon trifasciatus M. P. O.
330. Chaetodon ornatissimus Sol. O,A.
331. Chaetodon collare Bl. O.
332. Chaetodon strigangulus Gmel. O,A *
333. Chaetodon auriga Forsk. Y,O *
334. Chaetodon plebeius Gmenl. A *
335. Chaetodon argentatus Sm. & R. O,A *
336. Chaetodon kleinii Bl. O *
337. Chaetodon punctato-fasciatus Cuv. A *
338. Chaetodon unimaculatus Bl. O *
339. Heniochus acuminatus L. O.
340. Forcipiger longirostris Brouss. A *
341. Holacanthus lepidolepis Blk. O.
342. Holacanthus lamarck Lac. (subsp. japonicus Schm.). O *.
343. Holacanthus nicobariensis Bl. Schn. (=H. bishopi Seale). O.
344. Holacanthus tibicen C. V. O.
345. Microcanthus strigatus Cuv. O.
346. Hemitaurichthys zoster Benn. (=H. polylepis Blk.). A *
347. Zanclus canescens L. O,A *

Fam. Hepatidae.

348. Hepatus olivaceus Bl. O.
349. Hepatus fuliginosus Less. (=H. matoides C. V.). O.
350. Hepatus triostegus L. O.
351. Hepatus bariene Less. (=H. dussumieri C. V.). O.
352. Hepatus lineatus Gmel. O *
353. Hepatus aliala Less. (subsp. japonicus Schm.). O *
354. Hepatus elongatus Lac. (=H. nigroris C. V.). Y,O,A *
355. Zebrasoma flavescens Ben. O,A.
356. Zebrasoma veliferum Bl. A *
357. Naso unicornis Forsk. O.
358. Naso tuberosus Lac. O.
359. Naso brevirostris C. V. O.
360. Naso hexacanthus Blk. A *
361. Prionurus microlepidotus Lac. O.

Fam. Siganidae.

362. Siganus puellus Schl. O.
363. Siganus lineatus C. V. O.
364. Siganus fuscescens Houtt. O.
365. Siganus rostratus C. V. O.
366. Siganus corallinus C. V. O.
367. Siganus punctatus Bl. Schn. O.
368. Siganus virgatus C. V. Y,O.
369. Siganus tetrazonus Blk. O.
370. Siganus concatenatus C. V. Y,O *
371. Siganus doliatus Cuv. Y *

Fam. Balistidae.

372. Balistes niger M. P. O.
373. Balistes vidua Rich. O.
374. Balistes fuscus Bl. Schn. O.
375. Balistes capistratus Shaw. O.
376. Balistes flavimarginatus Rüpp. O.
377. Balistes chrysopterus Bl. Schn. O.
378. Balistes conspicillium Bl. Schn. Y *
379. Balistes bursa Lac. O,A *
380. Balistapus aculeatus L. O.
381. Balistapus verrucosus L. O *
382. Balistapus undulatus M. P. O.
383. Erythrodon niger Rüpp. Y *
384. Canthidermis rotundatus. Y,A.

Fam. Monacanthidae.

385. Alutera scripta Osb. O.
386. Alutera monoceros Osb. O.
387. Monacanthus chinensis Osb. O.
388. Monacanthus pardalis Rüpp. O *
389. Monacanthus setifer Benn. Y.

Fam. Ostraciidae.

390. Ostracion cornutus L. O *
391. Ostracion cubicus L. O *
392. Ostracion diaphanus Bl. Schn. O *

Fam. Tetrodontidae.

393. Sphaeroides ocellatus Osb. O.
394. Sphaeroides alboplumbeus Rich. O.
395. Sphaeroides sceleratus Gmel. A *
396. Tetrodon hispidus L. O.
397. Tetrodon meleagris Bl. Schn. O.

Fam. Diodontidae.

398. Diodon holacanthus L. Y,O.
399. Diodon hystrix L. O.

Fam. Scorpaenidae.

400. Sebastopsis guamensis Q. G. O.
401. Scorpaenopsis gibbosus Bl. Schn. O.
402. Scorpaenopsis cirrhosus Thunb. A *
403. Synanceia verrucosa Bl. Schn. O.
404. Pterois volitans L. Y.

Fam. Platycephalidae.

405. Platycephalus indicus L. O.
406. Thysanophrys crocodilus Til. O,A.

Fam. Latilidae.

407. Latilus japonicus Houtt. O.

Fam. Osphromenidae.

408. Polyacanthus opercularus L. O.

Fam. Pleuronectidae.

409. Platophrys myriaster Schl. O.

410. Platophrys pantherinus Rüpp. A *
411. Pseudorhombus arsius Buch.-Ham. (=P. polyspilos Blk.). A *

Fam. Soleidae.

412. Zebrias japonicus Blk. O.
413. Pardachirus pavoninus Lac. O.
414. Trulla itina Sn. O.

Fam. Gobiidae.

415. Mogurnda obscura Schl. O.
416. Vireosa sakurai Schmidt. O *
417. Valenciennea muralis Q. G. Y.
418. Doryptena okinawae Sn. O.
419. Eviota abax Jord. & Sn. O.
420. Eviota viridis Waite (=E. zonura Jord. & Seale). O.
421. Eleotris fusca Forsk. O.
422. Hetereleotris arenarius Sn. O.
423. Gnatholepis sindonis Sn. O.
424. Rhinogobius nebulosus Bl. Schn. O.
425. Rhinogobius giurinus Rutt.
426. Ctenogobius abei Jord. & Sn. O.
427. Ctenogobius bernadoui Jord. & St. O.
428. Ctenogobius caninus C. V. O.
429. Ctenogobius campbelli Jord. & Sn. O.
430. Ctenogobius gymnauchen Blk. O.
431. Bathygobius fuscus Rüpp. (=Mapo crassipes Jord. & Seale). O.
432. Mapo aelosomus Ogil. O.
433. Amblygobius naraharae Sn. O.
434. Periophthalmus cantonensis Osb. O.
435. Zonogobius semidoliatus C. V. O.
436. Xenisthmus proriger Sn. O.
437. Tridentiger obscurus Schl. A *

Fam. Pteropsaridae.

438. Parapercis hexophthalma. O.
439. Parapercis tetracantha Lac. O.

Fam. Callionymidae.

440. Synchiropus ocellatus Pall. O.

Fam. Gobiesocidae.

441. Aspasma minima Doed. O.
442. Aspasma misakia Tan. O.

Fam. Blenniidae.

443. Enneopterygius etheostoma Jord. & Sn. O.
444. Enneopterygius minutus Gthr. O.
445. Alticus ellipes Jord. & St. O.
446. Alticus novemmaculatus Sn. O.
447. Salarias fasciatus Bl. Schn. Y.
448. Salarias lineatus Blk. O.
449. Salarias andersoni Jord. & St. O.
450. Salarias muscarus Sn. O.
451. Salarias sinuosus Sn. O.
452. Salarias edentulus Bl. Schn. (=S. quadricornus C. V.). O.
453. Petroscirtes loxozonus Jord. & St. O.
454. Petroscirtes elatus Jord. & Sn. Y.
455. Enchelyurus hepburni Sn. O.
456. Cristiceps flammeus Jord. & St. O.

Fam. Congrogadidae.

457. Congrogadus subducens Rich. Y.

—March 28, 1930, Leningrad.

Rice and Vitamine

By SUYEO NAKANO
Nippu Jiji Tokyo Correspondent

In accordance with the urgent advice of Dr. Junijiro Shimazono, Professor of its Medical Department, the Tokyo Imperial University has prohibited eating of cleaned rice. Dr. Shimazono was also urging the necessity of enacting a law prohibiting the use of cleaned rice to his fellow members of the Population and Foodstuff Research Committee.

Professor Shimazono, holding that rice containing embryo is most suitable to the Japanese life, demands the prohibition of sale of rice which does not contain a sufficient quantity of embryo. Dr. Tsune Sayeki, chief of the Nutrition Laboratory, is opposed to Dr. Shimazono's contention. His counter-statement based on prolonged investigations, prevented Dr. Shimazono's argument from assuming a concrete shape in the Population and Foodstuff Research Committee.

Dr. Shimazono lays stress on the degree of cleaning rice so as not to spoil its embryo, inasmuch as it is his idea to solve the issue taking the quantity of embryo into consideration in respect to rice's consumptive economy and health efficiency. Dr. Sayeki points out that Dr. Shimazono's contention is not based on scientific stubborn facts, which he ascertained through investigations lasting ten years.

Dr. Sayeki emphasizes it is extremely inadvisable to prohibit the use of cleaned rice by enacting a law, inasmuch as rice's embryo alone does not represent its vitamine. There are various theories as to the degree of cleaning rice. About twenty years ago, an argument was raised for fixing the standard of cleaning on the basis of phosphorus contained therein. Scientists found it vitally defective.

Next, a theory of rice dyed with iodine was tested, but it could not arouse attention outside of laboratories. Subsequently, the Lister Laboratory in England dis-

covered that rice's embryo contained a good quantity of vitamine. Further investigations demonstrated, however, that vitamine was abundantly contained in rice's other parts than embryo.

Vitamine's quantity decreases even of rice containing embryo when it becomes older. Certain kinds of rice retain embryo after cleaning, but others do not. Dr. Sayeki's laboratory has since then discovered a new process of ascertaining vitality of grain of rice without regard to embryo. He believes Dr. Shimazono's proposal to legally prohibit the use of cleaned rice detrimental to the future life of the Japanese nation.

On the other hand, Dr. Shimazono points out that the continued use of cleaned rice is apt to contract beri-beri and cognate maladies. For three years past he was invariably recommending the use of rice only partly cleaned. He uses such rice at his own home, and induced the management of the Tokyo Imperial University hospital to do so. Its result is naturally very fine.

He desires that 60 to 80 per cent of rice's embryo will be retained in spite of cleaning. The nation's health will be ensured, if such rice should be always eaten. Dr. Kenji Futaki's uncleaned rice might be all right in the long run, but it is likely to cause loose bowels at first. The Nutrition Laboratory's rice cleaned 70 per cent is not necessarily bad, but Dr. Shimazono believes that rice retaining the bulk of embryo is better. There will be no technical difficulty in enforcing the prohibition of the use of cleaned rice, as the difference of completely or partly cleaned rice may be easily found by policemen, for instance.

Rice pounded so as to retain embryo is different from ordinary time-honored pounder. Dr. Shimazono contends that the Japanese may preserve health by eating embroyologic rice as the principal diet, in case they cannot spare a sufficient amount of money to side dishes. Students who could take a sufficient nutrition while eating rice not completely cleaned in the country usually become more or less slender when they return to the city and eat completely cleaned rice.

The use of embryologic rice will also indirectly reduce cases of tuberculosis, pleura, etc. Those boys and girls who are not big enough or strong enough may rebuild their physiques by continually eating embryologic rice, according to Dr. Shimazono. One's financial means may prevent him from taking a sufficient amount of meat. Meanwhile, it is advisable that one will take much more bean, bean-curd, etc.

Professor Susumu Matsumura of the Chiba Medical College has ascertained that beri-beri is due to peculiar bacilli. He conducted prolonged investigations in Taiwan, China, French Indo-China, Malay Peninsula, South Seas, Hawaii, California, Brazil, etc. His researches were made among natives and Japanese emigrants. They explicitly demonstrated that beri-beri was traceable to A and B beri-beri bacilli, which has been remaining a mystery among medical circles for twenty years past.

Dr. Matsumura's articles on the subject have been recently submitted to the Imperial Academy. They are also to be translated for the perusal of European and American scholars. Dr. Matsumura concedes that beri-beri is chiefly found among races usually eating rice, but it is occasionally noted among those races not eating rice. It may be inferred, however, that eating of rice is more likely than anything else to form one of the elements of beri-beri bacilli.

Japan's national drink, sake, is made of rice. Japan will have to import foreign rice so long as the Japanese drink sake and the population in this country continues to increase. But it may be noted that boys and girls in Japan are gradually accustomed to foreign food. Some of them prefer bread to rice.

Until about twenty years ago young men in Japan were used to complain that they could not renew their energy without having rice and miso or bean paste soup at breakfast. Now part of the boys and girls decline miso soup at breakfast.

Shellfish of Hawaii and the Introduction of Edible Species

By J. M. OSTERGAARD
At the Pan-Pacific Research Institute

The familiar term "shellfish" includes a vast assembly of marine animals which belong to widely differing groups of organisms, inhabiting chiefly the shoal water near the seashores. Clams, crabs and sea-urchins are examples of shellfish and all of them possess a hard external shell, while they are remotely separated anatomically.

The most important by far economically, as well as in number of forms, is that division of shellfish technically called Mollusca, which includes the clams, oysters, scallops, mussels, snails, squids, cuttlefishes, octopuses, etc., and which may be encountered in every part of the temperate and tropical shore regions of the earth.

Owing to the southerly latitude of the Hawaiian Islands, it is natural to suppose that the molluscan fauna would be a tropical one. This is indeed the case. The Hawaiian shores are inhabited by genera of mollusks common to the tropical Indo-Pacific, whose species are commonly represented in the Indian Ocean and in the South Pacific. The number of marine mollusks in Hawaiian waters is estimated at about 1,500 species, of which probably not more than 15 per cent are endemic, i.e., peculiar to Hawaii.

As to the edible species in Hawaii, a great number of forms are used as food by the Hawaiian people, as well as by other races; while the Caucasians, now constituting so large a percentage of the population of Hawaii, rarely ever add any of the local forms of mollusks to their menu. It seems to be largely a matter of prejudice on the part of the latter against food of this sort that limits their choice to certain exotic oysters, clams, mussels, scallops, etc, rather than the actual difference in taste.

While studying the mollusks of the Tonga Islands in 1926, I learned through corroborative statements of the natives that, out of the large number of species of bivalved and univalved mollusks populating their shores, all but those of insignificant size were used as food. Evidence that the Hawaiian people also, before the advent of other races of man, used as food a larger variety of mollusks than are today used by them, is had in the fact that over extensive areas on the leeward side of the island of Oahu will be found mixed with the surface soil, the shells of mollusks that must have been derived from the so-called kitchen middens, from which rain storms washed them down to lower levels.

Of now living native oysters only two small species about the size of a dollar (*Ostrea sandwichensis and Nanleyana*) are known. The former occurs in great quantity on wharf pilings and on rocks in bays and inlets. Both of these oysters are discarded as food, owing, perhaps to their small sizes. Two species of fossil oysters are known in Oahu from marine strata high above the level of the sea. The one (*Ostrea retusa*) occurs chiefly in the Pearl Harbor region, where in a railroad cut at Waipio a deposit of shells reaches a thickness of about two feet. This is an elongated form about the size of the marketable eastern oyster. The other fossil oyster (*Ostrea bryani*) has been found in a limestone quarry near Waianae. This is a giant, the size of a dinner plate, the valves of one specimen attaining the weight of four pounds and nine ounces. These oysters, not known in the living state anywhere, are presumably of Pleistocene age.

The natural dispersal of marine mollusks from one region to another and the factors controlling it have been subject to much consideration. Some investigators maintain that if sufficient time be given, every species will by some means gain

access to every portion of the globe, and that the absence of old and well-established species in regions outside of their habitats is due, not to their inability to reach those regions, but to their failure to adapt themselves to conditions in their new environments. On the other hand, other investigators recognize insurmountable barriers, principally in the form of vast expanses of ocean. We have evidence of much truth on both sides, and we may confidently anticipate through continued research to gain additional important light on this vital principle of biology.

It may be safe to say that one of the most important factors in distribution, as applied particularly to the marine snails, or gastropods, is the free-swimming larval stage—a stage in which the larva, barely visible to the unaided eye, is transported by tides and currents for weeks or perhaps for months, until it has past this remarkable stage of its development, called the veliger, and assumed the form of the adult. Out of 65 species of gastropod mollusks, belonging to about 20 genera, whose larvae were studied in the Marine Biological Laboratory at Waikiki, only one was found to have no free-swimming larval stage. Owing to defects in the artificial laboratory conditions under which the larvae were kept, success in carrying any of them through the free-swimming period has not as yet been met with. The best record is 21 days from the time of hatching.

Some gastropod mollusks appear to spawn in the warmer months of the year, while others apparently choose the cooler season of December, January and February. Many species migrate at breeding season from the deeper water beyond the coral reefs into shoal water to deposit their spawn. The egg-structures vary greatly in pattern in different genera and are often of extremely elaborate designs. As many as 10,000,000 eggs have been estimated in one single egg-structure.

It is hoped that the near future may see the successful establishment of choice edible forms of clams and oysters in Hawaii, introduced from other parts of the Pacific. Experiments of that sort have been carried on for a number of years and have resulted in the successful growth and natural propagation of two of Japan's most desirable food clam (*Paphia phillipinarum and Cytherea meretrix*).

The Pismo clam of California and a few species of oysters, including one or more mainland varieties, have been set out in suitable places along the Oahu shores. The chief obstacle to success with the introduced oysters seems to lie in their failure to spawn. Biological factors difficult of detection enter into the question here. Very little is known about the conditions required by marine animals in general; thus we are unable to explain why so many of the Hawaiian marine mollusks are extremely rare in Hawaii but abundant in the South Pacific, even in latitudes as far south of the equator as Hawaii is north of it, and with similar ocean temperatures.

The Fresh Water Life of a Dry Island

By JAMES G. NEEDHAM

This is a brief summary of some observations made on San Clemente Island in April, 1923. I was privileged to accompany a botanical collecting party from Pomona College that was organized and conducted by Dr. P. A. Munz. I was duly warned that there would be no good collecting of fresh-water animals for lack of springs and permanent streams on the island. But I judged that a bit of land where many thousands of sheep find pasture would have some fresh water, and that that water would have some inhabitants, and that there might be some interest in finding out what they are. The following pages are to tell what I found.

San Clemente Island is the southernmost of the Channel Islands that border the coast of southern California. It lies out in the Pacific Ocean some fifty miles south of the port of San Pedro, with the better known Santa Catalina Island midway between. Unlike Catalina, with its serrated crest, San Clemente is an elevated block of land some twenty-one miles long and four wide.

The edges of the block are precipitous, especially the higher one on the mainland side; and the upland intervening portion is undulating plain, with a gentle slope seaward. The materials are of volcanic origin. Their elevation has been accomplished by a succession of uplifts, and terraces, in a series marking ancient sea beaches, parallel the shores. These are very prominent features of the landscape along the southwestern side. On the opposite edge of the block, the ridgelike summit of the island reaches an elevation of 1964 feet.*

*An excellent account of the geology and topography of the island by W. S. T. Smith will be found in the 18th Report of the U. S. Geol. Survey, Part II, page 493.

No Weather Bureau records are available for the Island of San Clemente but a ten-year record made on the neighboring island of Catalina gives average precipitation by months as follows:

Jan. 3.03, Feb. .293, Mar. .215, April .70, May .19, June .04, July trace, Aug. .01, Sept. .17, Oct. .49, Nov. .49, Dec. .19.

The upland plain is treeless. Though it is all one great sheep-pasture, it is also grassless, save for worthless immigrant foxtail (Hordeum) grasses. The sheep feed upon low succulent half shrubby native plants, chief among which appears to be a species of Lyceum, allied to our familiar matrimony vine but smaller, fleshy, and of very different appearance. The few trees upon the island are deep down in the gorges that intersect the edges of the block, or they are on the small alluvial fans that border the mouths of the larger streams. The upland looks like the Western Kansas plains with wide "draws" where gentle slopes converge to low points in the edges of the block, from which the flood waters descend the precipitous slopes, cutting short, steep-walled gorges.

Relatively permanent fresh water is to be found on the island in two very different situations: in the sheep-pools on the upland and in the plunge basins at the foot of the waterfalls in the rocky gorges. Both are refilled with fresh rain water in every storm and both are stagnant between precipitations.

The population of both sorts of pools was very scanty in kinds though abounding in individuals of the few kinds present. Not a vertebrate animal of any sort did I find in either kind of pool.

In the sheep-pools of the upland two species of insects and one crustacean were very abundant:

1. Midge larvae (*Chironomus prasinus*), spun their filmy tubes everywhere in the mud of the bottom.

2. Water boatmen (*Arctocorixa inscripta*) bobbed about everywhere over the surface of the bottom mud. The grass stems that hung in the edge of the water were completely encrusted with their white eggs.

3. There was a pale, flesh-tinted Ostracod crustacean (name not yet determined) swimming in the edges of the

pools or lying on its side on the white bottom at the shore line. In several places where the shore was bare and very gently sloping I saw a belt of these ostracods, millions of them, lying on the mud at the very margin, covered only by the surface film of the water, forming a fringe of soft pink color about the water line.

There were a number of aquatic carnivorous beetles in the sheep-pools, among which were noted the following: *Eretes sticticus,* not common; *Rhantus binotatus,* not common; *Agabus confertus,* common; *Deronectes striatellus,* very common. Running about on the mud and shore were two shining green species of *Bembidium B. insulatum,* the larger and less common, and *B. flavopictum,* smaller and abundant.

Two small Staphylinid beetles were also present in some numbers, running about indifferently on the surface of the mud or on the water: *Echidnoglossa eximius,* the larger slender, less common species, and *Trogophlaeus giliae* the smaller depressed more common one.

Occasional craneflies (*Trimicra pilipes*) and Dolichopods (*Hydrophorus aestuus*) and Ephydrids (undetermined) flitted about the surface of the pond, and a little spider (*Bathyphantes pacificus*) occasionally dropped down upon the surface from the grass overhanging the steeper margins. All in all, it was a scanty fauna.

The fauna of the rockpools was still more scanty. More than 90 per cent of it was mosquito larvae. The remainder of it was beetles and little flies and a very few adult water boatmen. The beetles were in part aquatic (*Agabus confertus*) and in part shore dwellers that come out to the water to forage (*Bledius ruficollis*) and *Echidnoglossa gracilis.* Two of these, it will be noted, were of the same species found in the sheep pool, as were also the water boatmen.

Not a dragon fly, may fly, stone fly, or caddis fly was seen; and on the land, not a grasshopper, nor a sign of a rodent. The little native fox of the island feeds on ground beetles (*Carabidae*) of which one species (*Amara insularis*) was abundant and two others (*Eulabis grossa* and *Nesostes robustus*) were common under stones all over the upland.

Another striking thing about the island's population is the cosmopolitan character of many of the forms present. Its one butterfly is the Painted Lady, *Vanessa cardui,* a true cosmopolite. The little hairy-legged cranefly, *Trimicra pilipes* is perhaps the same as *T. anomala* which Dr. C. P. Alexander says is "Probably the most widely distributed cranefly in the world." The midge, *Chironomus prasinus,* has been found wherever careful collecting for midges has been done. The aquatic species, even the most delicate among them, seem to fare about as do the terrestrial at the hands of the world's agencies of distribution.

Hawaii's Water Supply

By MAX M. CARSON,
District Engineer of Water Resources, Branch of the U. S. Geological Survey
Pan-Pacific Research Institution, April 4, 1930

Water supply, as I use the term here, means a supply of fresh water for drinking, cooking, washing, watering our lawns and gardens, for use in boilers and condensers, in nearly every kind of manufacturing process, in the disposal of sewage and factory wastes, in the development of water power, the irrigation of commercial crops, for navigation, and for fisheries and recreation.

All of these uses, except navigation, are of considerable importance in Hawaii; and except for power, fisheries and recreation, they are vital.

Although some ocean-going vessels do fill their fresh water tanks with distilled sea water, generally we depend on natural distillation over which we have no control. We cannot choose where or when the rain will fall and therefore the water supply problem is one of getting the water from where it falls as rain to the place where it is desirable to use it.

The Hawaiian Islands lie in the path of the northeast trade winds and the mountains along the windward side of the islands catch most of the rainfall. The heaviest rainfall occurs between elevations of 2,000 to 5,000 feet.

Where the mountains are lower than 2,000 feet, most of the rain-clouds pass over the top and the rain falls mostly on the lee side, if it falls at all. And where the mountains are more than 5,000 feet high, they catch practically all the rain on the windward slopes; and the lee sides are extremely arid. Consequently, we have very wide differences in mean rainfall within very short distances. Oahu, the western end of Molokai, the neck between East and West Maui and the islands of Niihau, Lanai and Kahoolawe, are examples of the first condition; and East Maui and Hawaii are examples of the second condition. The intermediate condition where the tops of the mountains lie between the belt of maximum rainfall produces very high precipitation distributed over areas of high elevation but the extent of distribution to leeward decreases with the increase of elevation of the crest or peak. Prominent peaks, unsheltered by other surrounding mountains, such as Waialeale and Kawaikini on Kauai, and Eke and Kukui on Maui, extending to the upper limit of heavy rainfall, and catching, as they do, the winds from all directions, have annual precipitations of 30 to 50 feet concentrated near the tops. The Kona coast of Hawaii, although on the southwest side of the island, receives a lot of southwest wind, possibly due to eddying, and is, therefore, somewhat in the same class as other windward slopes.

In the collection and distribution of this water from the rainy to the arid regions or even from one place to another in the rainy regions, the character of the soil plays an exceedingly important part. Where it is relatively impervious and fairly large drainage areas have developed, as on Kauai, the water collects into surface streams of considerable size from which it can be led by earth ditches to the point where it is to be used. But where the surface is open and porous, as the fresh lavas on Hawaii, it sinks into the soil and only the heaviest storms produce any surface run-off at all. All variations of soil texture between these two extremes occur in the Hawaiian Islands. And even in the areas where the soil is tightest in these islands, there is probably considerable loss from seepage.

In many countries the character of the soil plays an important part also in the quality of the water, but in Hawaii it is almost universally so insoluble that practically all our fresh water supplies are very soft and pure. Most places in the islands, water can be taken from the tap

for use in storage batteries without any treatment whatever.

The water that seeps down into the ground either strikes denser material that forces it laterally to the surface as springs or continues on downward to sea level. Here it is forced laterally over the underlying sea water by the pressure of fresh water above and enters the ocean either as surface or subaqueous springs. In some places the coastal plain is partly composed of an impervious material that holds back lateral movement and builds up a pressure causing artesian conditions.

Thus Hawaii has rainfall rivalling, if not exceeding, that of any other part of the world and also areas of extreme aridity. And it has areas of comparatively high percentage of runoff and also areas of practically zero runoff; with all gradations and innumerable combinations in between. And this has made necessary the adoption of a diversity of methods for the recovery and use of the waters.

Kauai, generally reputed to be the oldest island in the group, has, roughly, the shape of a truncated cone, the top rising to from 3,500 to 5,000 feet. Drainage areas are relatively large; and streams, particularly on the windward side, have more nearly uniform flow than elsewhere in the Territory. Moreover, though the streams all head in the rainy seasons at the top, their courses radiate in nearly all directions. Most of the development, therefore, has been by conducting the water from the stream, through earth ditches, to the adjacent fields—one stream with its tributaries supplying one or more ditches at different elevations. Unfortunately, the large streams on the windward side have developed their maximum flow at such low elevations that it has seemed impracticable to lead much of the water from them around to the lee side where the need is greatest. Consequently the plantations on the lee side have looked to the ground water supply to augment what they have been able to collect from ditches.

McBryde's have developed electric power at Wainiha, brought that over to Hanapepe by means of a long transmission line, and used it to pump ground water from pits and collection galleries in the bottom of Hanapepe Valley. Their pumps also raise some of the water from Hanapepe River to their cane fields on the kula land above. Koloa and Kekaha have drilled artesian wells. And Kekaha has made a very unusual development at the Mana swamps by pumping out the swamp water and thus lowering the water table so that the land can be planted and then watered with the same water, and leaving an excess of water for use elsewhere.

Oahu has two ranges of mountains roughly parallel to each other and at right angles to the prevailing winds. The leeward or Waianae range is therefore protected by the windward or Koolau range and gets very little rain except on Kaala, which is nearly 2,000 feet higher than the mountains to windward. On account of the relatively low elevation of the Koolaus, with respect to the heavy rain belt, much of the rain on that range falls to leeward of the crest and several important streams, therefore, flow to leeward. However, much the greater part of the water either runs off as flood flow or disappears in seepage. The Waiahole ditch system intercepts the principal streams on the windward side and brings all the ordinary high level flow from them through the mountains to the leeward plains. On this island, however, most of the water lost to the streams in seepage is caught under impervious materials and held back from the sea in artesian formations. The discovery of this underground reservoir led to the rapid development of new agricultural areas irrigated by supplies drawn from artesian wells and to the substitution of artesian water for surface water almost entirely in the City of Honolulu. Some development also of the ground water supply not under artesian pressure has been made at Waianae and Nanakuli, and the Honolulu Stadium waters its grass with water pumped from a surface

spring. Rather large quantities of water of this character are escaping into the sea along the coast, notably around Pearl Harbor, and are now the subject of study by the Board of Water Supply of Honolulu, with a view to its possible utilization.

Molokai lies nearly east and west in one range of mountains. The east end rises to about 4,000 feet and catches on its northeast side practically all the rain that falls on the island. The west end is too low to get any appreciable amount of rain and is also partly protected by the higher mountains to the east so that there are no streams at all except flood channels on that end. Domestic water is obtained from small streams and springs near the top of the ridge, but the fairly large streams on the northeast coast are all running to waste except in Halawa Gulch where some irrigation is carried on in the bottom of the valley. The practical difficulty of bringing this water by ditch and tunnel to the arid land on the western end has so far prevented such development.

Attempts to obtain artesian water on Molokai have thus far met with failure and there is no reason at this time to anticipate any success along that line in the future. However, some shallow wells extending to the ground-water table just above sea level have been quite successful and it is probable that further development of this supply will be worth while.

Maui has two main mountain masses separated by a low neck of land. West Maui, like Kauai, is roughly conical, rises to about 5,000 feet elevation, and the top receives a very heavy rainfall. Streams radiate from the central mass on all sides, but the heaviest flow is to the windward. Water has been brought out in ditches from the windward side to the drier lands on the east and west and additional supplies of non-artesian ground water have been obtained by sinking shafts to the water table to about sea level.

East Maui, although much the same shape, rises to elevations of 7,000 to 10,000 feet so that the top projects well above the rain belt, the top and lee side are very dry, and the windward side, below 5,000 feet elevation, is very rainy. The water runs down narrow gulches directly toward the sea, and ditches have been constructed along the side of the mountain, running from one gulch to another, cutting through the ridges in tunnels, collecting water from some thirty or more streams, and delivering it to the low-lying, dry land on central Maui. These ditches have been constructed, one below the other, so that during floods the lower ditches catch water that passes over the intakes of the ones higher up the slope. Springs occur in some of these gulches at from 500 to 800 feet elevation that may justify further development still lower down than the present ditches.

On the neck of land between these mountain masses, sumps and collection galleries have been dug to intercept the ground water near sea level and several pumping plants have been installed capable of delivering large quantities of water from that source. During dry seasons water from these supplies is sometimes pumped to an elevation of about 800 feet for the irrigation of sugar cane.

It is interesting to note that on Maui the soil is so porous that it is generally considered economical to line the ditches with concrete to prevent excessive seepage.

Hawaii, in part, at least, the newest island in the group, as some of it is still in the making, and much the largest island, is composed of four large mountain masses; the Kohala mountain rising to about 5,500 feet on the north; Hualalai rising to about 8,300 feet on the west, and Mauna Kea on the east and Mauna Loa on the south, both nearly 14,000 feet high. The northern (Waimea) plateau between the Kohala mountains, Hualalai and Mauna Kea is about 3,000 feet high, while the southern plateau (Humuula) between Mauna Loa, Hualalai and Mauna Kea is about 6,000 feet high. Hence the island presents an almost unbroken face to the prevailing winds, at the maxi-

mum rainfall elevations. The whole windward coast line is therefore streaked with innumerable small (and not so small) streams, running from around 4,000 or 5,000 feet down to the sea. Irrigation is unnecessary and the chief use of the water is to flume the cane from the uplands to the mills (and, of course, operate the mills). The tops of the three highest peaks, the southern and the northwestern coasts, are arid. The western coast gets a sea breeze much of the time, even when there is a trade wind blowing from the northeast against the "windward" side of the island. This sea breeze brings a considerable rainfall, sufficient to produce a good forest growth but insufficient to produce stream flow heavy enough to overcome the extremely high rate of seepage except during occasional floods. A few small water holes and swamps in this area are formed by basins of impervious lava, but few, if any, high level springs exist, though there are a number of large springs at or near sea level. If it were not for the rapid rise of the land from the sea, making excessive lifts necessary, it is probable that a very considerable amount of water could be obtained along this coast by developments similar to those in central Maui. As it is, however, even domestic water must usually be obtained by catching rain water on the roofs of houses or on corrugated iron water sheds, and stored in tanks for use. Irrigation is from rainfall only.

Three inherent obstacles exist to bringing the excess water from the windward slopes to the dry areas on the lee side. First, the distances on Hawaii are so great that it would be necessary to take a very large amount of water around in order to pay for the enterprise. Second, the land mass of the island rises so rapidly that at any elevation where such a large amount could be utilized or a ditch economically be constructed, the combined stream flow is too small to furnish the necessary water. Third, the soil is so porous that lined ditches would be necessary for the greater part of their length and at the point of use, probably an excessive quantity of water would be necessary to grow a crop. At the northern end of the island, the Kohala ditch system and the Hamakua ditch system do bring out water from the Kohala mountains to serve adjacent lands but this is only a very small part of the area on the island that could use water for its further development.

So far as I know, no artesian water has been found on the island of Hawaii and even if it were found it would probably be uneconomical to use it in most cases on account of the excessive high lift that would be required to raise it to the level of the fields needing it. On the southern side of the island small flows have been developed at high elevations for fluming purposes, by intercepting the percolating water with tunnels driven along the plane of contact where one relatively permeable bed of material overlays a less permeable one. This suggests possibilities in the westerly or Kona region but would necessitate a very detailed investigation which has not yet been undertaken.

So the Hawaiian islands have a lot of land that needs water and a lot of water going to waste with no present economic method proposed for bringing the two together.

I have little information concerning the water supplies of Niihau, Lanai and Kahoolawe, except that water is very scarce on these islands and I do not feel competent to discuss them in any detail.

No special consideration has been given in Hawaii to a supply of fresh water for fisheries, recreation or navigation, because the streams are too steep and full of rapids for navigation above tide water, and recreation and fresh water fishing have not, as yet, assumed sufficient importance to compete with commercial demands. However, nearly all Hawaiian streams have oopu, shrimps, frogs, fresh water shell fish, known as Hihiwai or wi, and some of the colder mountain streams have been stocked with trout. An attempt has been made to stock with salmon but whether with success has not been dem-

onstrated. The recreational possibilities in the beautiful mountain streams, waterfalls, innumerable pools suitable for bathing and swimming, have been given scant attention, and in some localities, notably on parts of Oahu, they conflict with the necessity of protecting the watersheds for domestic supply and the forests from the encroachment of hikers.

Water power in the Hawaiian Islands has in the main been subordinated to the use of the water for domestic supply, irrigation and manufacture, and is usually merely a by-product of one of these uses; that is to say, water power plants, where they do exist, are usually in the line of transportation of the water to some other use. There are quite a large number of small plants along ditch lines where there are suitable drops available but very few where the water is not subsequently used for some other primary purpose.

One of the greatest difficulties in the complete utilization of the surface water supply throughout the Territory is the flashy character of all the streams, and the general absence of suitable storage facilities. Our rainfall comes, generally, in short heavy showers, our stream courses are very steep and short, drainage areas small, and the result is that the runoff occurs largely in quick, flashy floods that last only a few hours at the time. To utilize this flood water requires storage facilities. But the very steepness of the stream beds which contributes to their flashy character makes reservoir sites of any considerable capacity exceedingly scarce. The Wahiawa Reservoir on Oahu is the only one in the Territory, that I know of, that controls the entire seasonal flow of the streams that feed it. Another such reservoir is projected on the Waiakoali on Kauai, but has not yet been built. There may be a few small streams elsewhere in the islands that could be controlled in this way. But in the main, the surface water must be used as it comes.

This condition gives exceptional importance to the development of natural aids to storage. Artesian waters are stored underground. The dry weather flow of the streams comes from rain waters that have been stored in the soil. And the non-artesian ground waters which provide the supply for such developments as those on central Maui are stored in the ground. All these are supplied by seepage. Anything, therefore, which will retard the flood runoff and allow the water to seep into the ground and percolate downward slowly, will do one (or all) of three things: increase the dry weather stream flow, increase the supply of ground water near the surface, or increase the supply of artesian water. The best known agent for doing this is a suitable forest cover. The Territory has recognized the importance of maintaining such forest cover and most of the areas subject to heavy rainfall are now in forest reserve.

In this talk I have purposely refrained from the use of statistics because, were I to begin quoting figures, the whole talk would inevitably become a mass of statistics. For the past twenty years the Water Resources Branch of the U. S. Geological Survey and the Division of Hydrography of the Territory, coöperating as a single organization, have been gathering and publishing statistics on the flow of surface streams and ditches, and for fifteen years they have been collecting data on artesian waters, the results of which will be published before long. And there is still much to be done in that line.